

## ANSWERS: Atomic Structure

1.  $\text{Al}^{3+}$  because it has 13 protons (+ charges) and only 10 electrons (– charges). It has only 10 electrons, as its electron arrangement as an atom was 2,8,3, and when it forms an ion, it loses three electrons to form an arrangement of 2,8 to have a full outer shell, which is more stable.

$\text{S}^{2-}$  because it has 16 protons (+ charges) and 18 electrons (– charges). It has 18 electrons, as its electron arrangement as an atom was 2,8,6, and when it forms an ion, it gains two electrons to form an arrangement of 2,8,8 to have a full outer shell, which is more stable.

$\text{Cl}^-$  because it has 17 protons (+ charges) and 18 electrons (– charges). It has 18 electrons, as its electron arrangement as an atom was 2,8,7, and when it forms an ion it gains one electron to form an arrangement of 2,8,8 to have a full outer shell, which is more stable.

An ionic bond is the attraction between a positive ion and a negative ion. It is formed because opposite charges will attract one another.

An ionic bond would not form between chloride ions and sulphide ions, as they both have negative charges because they have both gained negative electrons in order to form a full valence shell, and the ions with the same charge will repel each other.

### Elements 1 and 3: $\text{AlCl}_3$

Aluminium has a charge of +3. In order to have a neutral compound overall, one aluminium ion is required to cancel out the charge on three chloride ions with a combined charge of –3. The charge on the aluminium ion arises as it gives away three electrons in order to have a full outer shell. Because it has to give 3 electrons away and each chlorine has to accept one electron, in order to have a full shell, the ratio of ions required is one to three.

### Element 1 and 2: $\text{Al}_2\text{S}_3$

2.  $\text{CaCl}_2$

$\text{NaNO}_3$

$\text{Zn}(\text{NO}_3)_2$

Atom	Atomic number	Electron arrangement of atom	Electron arrangement of ion	Charge on ion
Mg	12	2,8,2	2,8	+2
Al	13	2,8,3	2,8	+3
O	8	2,6	2,8	–2

Magnesium ion has a charge of +2 and oxide ion has a charge of –2. A compound overall has to have no charge. Therefore the +2 charge of magnesium ion cancels out the –2 charge of oxide ion, and so therefore the ratio of ions is one to one. The charge on the ions arises, as magnesium has to lose two electrons in order to have a full outer shell and have a charge of +2, and oxygen has to gain two electrons in order to have a full outer shell and have a charge of –2. In order to do this, magnesium gives its two electrons straight to oxygen and the ratio is one to one of the two ions.

Aluminium ion has a charge of +3. In order to have a neutral compound overall, two aluminium ions with a combined charge of +6 are required to cancel out the charge on three oxide ions with a combined charge of –6. The charge on the aluminium ion arises as it gives away three electrons in order to have a full outer shell. Because it has to give 3 electrons away and oxygen has to accept two electrons in order to have a full shell, the ratio of ions required is two to three.

3.

	Atomic number	Number of protons	Number of electrons	Electron arrangement
$\text{F}^-$	9	9	10	2,8
Ne	10	10	10	2,8

Mg <sup>2+</sup>	12	12	10	2,8
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The difference between an ion and an atom is that an atom has a neutral charge as it has not gained or lost electrons and therefore has the same number of protons (+) and electrons (–) whereas an ion has a charge as the atom it was formed from has either gained or lost electrons to form a full outer shell and therefore has a different number of protons (+) from the number of electrons (–).

#### Explanation of charges

Fluorine has 9 protons and electron arrangement of 2,7. Neon has 10 protons and an electron arrangement of 2,8. Magnesium has 12 protons and an electron arrangement of 2,8,2.

Fluorine gains one electron to have a full outer shell. This is because it is in group 17 and has 7 valence electrons. For fluorine ion, the electron arrangement is 2,8.

Fluorine has a charge of –1 as it now has 10 electrons (negative charges) and nine protons (positive charges).

Neon has no charge as it has the same number of protons and electrons, as it has not gained or lost electrons, as it has an electron arrangement of 2,8 because it is in group 18 of the periodic table and its valence shell is complete.

Magnesium has 12 protons and electron arrangement of 2,8,2. Magnesium has two electrons in its outer shell as it is in group 2 of the periodic table, which it loses, so its outer shell is full (2,8) and it has a charge of +2, as it still has 12 protons (positive charges) and now has only 10 electrons (negative charges).

All three have the same electron arrangement as they have gained one electron, lost two electrons or have neither gained or lost electrons. The electron arrangement is 2,8 as this is the nearest possible stable electron arrangement for all three.

#### 4. a)

Atom	Atomic No	Electron arrangement of atom	Electron arrangement of ion	Ion symbol
Ca	20	2,8,8,2	2,8,8	Ca <sup>2+</sup>
F	9	2,7	2,8	F <sup>–</sup>
Cl	17	2,8,7	2,8,8	Cl <sup>–</sup>

b) F has 9 protons and electron arrangement of 2,7. Cl has 17 protons and an electron arrangement of 2,8,7. Both atoms are in group 17 of the periodic table as they both have 7 electrons in the valence shell. Both atoms gain one electron to have a full outer shell. For F ion the electron arrangement is 2,8, and for Cl ion it is 2,8,8.

F has a charge of –1 as it now has 10 electrons (–) and 9 protons (+). Cl has a charge of –1 as it now has 18 electrons (–) and 17 protons (+).

Ca has 20 protons and electron arrangement of 2,8,8,2. Ca has two electrons in its outer shell, which it loses, so its new outer shell is full (2,8,8) and it has a charge of +2, as it still has 20 protons (+) and now has only 18 electrons (–). Therefore Ca and Cl ions now both have the same electron configuration of 2,8,8.

#### 5. a) Description of ion

An ion is an atom or group of atoms that has lost or gained electron(s) **and** therefore carries a charge / full outer shell / stable.

#### Explanation of charges

Sodium has 11 protons and electron arrangement of 2,8,1.

Sodium has one electron in its outer shell, which it loses, so its outer shell is full (2,8) and it has a charge of +1, as it still has 11 protons (positive charges) and now has only 10 electrons (negative charges).

Oxygen has 8 protons and electron arrangement of 2,6. Oxygen has 6 electrons in its outer shell, and so it gains two electrons, so its outer shell is full (2,8) and so has a charge –2, as it still has 8 protons (positive charges) and now has 10 electrons (negative charges).

**b) Ratio of X ions to OH<sup>-</sup> ions**

1:3

**Charge of X**

Hydroxide ion has a charge of  $-1$ . Because there are three hydroxide ions overall, the total negative charge is  $-3$ . Therefore to form a neutral compound, X must have a charge of  $+3$ , as there is only one X ion in the formula. Therefore X loses three electrons to have a charge of  $+3$ .

**How to find group for X**

The only element between 11–18 that has three electrons in its valence shell, is aluminium in group 13, OR it must be in group 13 to have three valence electrons.

**What is X?** Aluminium.

**6. a) Definition of an ion:**

An ion is an atom or group of atoms that have lost or gained an electron and therefore carry a charge

Explanation of formation of ions: If the outer shell (valence) of an atom is not filled, the atom is unstable. It will react to gain a full outer shell to become more stable, by either losing or gaining electrons and making it into an ion.

Identification of Group:

Magnesium and calcium are in the same group on the periodic table (Group 2).

Explanation of why both form +2 ions: The atoms have the same number of electrons (two) in their outer shell. (*Students may give the electron configuration instead.*)

Both Mg and Ca need to lose two outer electrons to become stable by having a full outer shell. Each ion ( $\text{Mg}^{2+}$  and  $\text{Ca}^{2+}$ ) ends up with two less electrons than there are protons in its nucleus, so the ion has a charge of  $+2$ .

**b) Completion of table:**

Sodium: Group 1; 2.8.1;  $+1$

Beryllium: Group 2; 2.2;  $+2$

**c) Comparison of charges on ions:**

When these elements react, Na loses one electron and forms a  $+1$  ion, while Be loses two electrons and forms a  $+2$  ion in order to adopt the stable electron configuration. The hydroxide carries a charge of  $-1$ .

Explanation of formation of compounds:

An ionic compound is electrically neutral therefore all the positive charges must balance the negative charges.

Therefore it requires one  $\text{OH}^{-1}$  for each  $\text{Na}^{+}$  ion but two  $\text{OH}^{-1}$  ions for each  $\text{Be}^{2+}$  ion to form a neutral compound/ balance the charges.

**d) Atomic structure:**

Li – 3p, 3e

Electron configuration:

2.1

Explanation of neutrality

Li has equal numbers of protons and electrons, ie 3p and 3e. An atom is neutral when it has equal numbers of protons and electrons

## 7. Al<sub>2</sub>O<sub>3</sub>

electron configurations: Aluminium 2.8.3 Aluminium ion 2.8 Oxygen 2.6 Oxygen ion 2.8

Aluminium loses electrons to form positive ions. Oxygen gains electrons to form negative ions.

Because aluminium has three electrons in its outer (valence) shell, it loses 3 electrons, giving it a full outer shell / becomes stable, gaining a positive charge.

Each oxygen has 6 electrons in its outer (valence) shell so giving it 2 electrons gives it a full outer shell / becomes stable gaining a negative charge.

An aluminium ion has a charge of +3, while an oxide ion has a charge of -2, therefore three oxide ions are required to two aluminium ions, so that the final

formula is neutral. Ion formation and stable outer shell plus discusses why two aluminium ions are needed for every three oxide ions in terms of electron transfer, and/or balancing of charge to achieve a neutral compound. eg. Aluminium loses three electrons, so it has a full outer shell and a +3 charge.

Oxygen gains two electrons to gain a full outer shell and so it has a -2 charge. As the compound is neutral, three oxide ions are required to balance out the two aluminium ions as  $3 \times -2 \Leftrightarrow 2 \times +3$ .

*Evidence may come from diagrams showing electron transfer*

## 8. a) C: 6 protons, 6 neutrons (or diagram)

Electron configuration of 2.4 for <sup>12</sup>C

An atom is neutral when it has equal numbers of protons and electrons.

b) Mass is found by adding up protons and neutrons.

Electrons have negligible mass (and are not included in mass calculation).

Protons and neutrons make up (nearly) all the mass.

c) N: 7 protons, 6 neutrons (or diagram).

The mass of N and C are (nearly) the same.

12 and 13 refer to total mass of elements.

Mass of N is greater than C.

9. a) i) *Diagram showing 8 protons and 10 neutrons in nucleus, with 8 electrons orbiting, 2 in first shell, six in second.*

ii) Atom is neutral as there are the same number of positive particles / charges / protons as negative particles / charges / electrons

b)

Scientific name	Formula
Iron sulfate / Ferrous sulfate / iron (II) sulfate	FeSO <sub>4</sub>
Ammonium nitrate	NH <sub>4</sub> NO <sub>3</sub>
Potassium nitrate	KNO <sub>3</sub>
Calcium hydrogen carbonate	Ca(HCO <sub>3</sub> ) <sub>2</sub>

c) i) K in Group 1 Mg in Group 2; electron arrangement of K 2,8,8,1 Mg 2,8,2;

Charges on ions K<sup>+1</sup> Mg<sup>2+</sup>

ii) When these elements react, K loses one electron and forms a +1 ion, while Mg loses two electrons and forms a +2 ion, in order to adopt the stable electron configuration 2,8,8 and 2,8 respectively. Hydroxide carries a charge of -1, therefore it requires one OH<sup>-1</sup> for each K<sup>+</sup> ion but two OH<sup>-1</sup> ions for each Mg<sup>2+</sup> ion to form a neutral compound/ balance out the charges

10. i) protons = 19 electrons = 19 neutrons = 20

ii) protons and neutrons

iii) 2,8,8,1

b)i) ZnO K<sub>2</sub>SO<sub>4</sub> Ca(HCO<sub>3</sub>)<sub>2</sub>

ii) Copper hydroxide Lead sulfide Magnesium chloride

c) i) Charges are:  $3+$   $2+$   $3+$

ii) Hydroxide has charge  $1-$  so total negative charge is  $2-$ . To balance out charges and make a neutral species, charge on X must be  $2+$  to cancel out the  $2-$ .

11.a)

proton  $+$   
electron  $\ominus$   
neutron  $\bigcirc$

b) i) Diagram showing  $12 \times \bigcirc$  and  $11 +$  in nucleus; 11 electrons orbit nucleus arranged 2, 8, 1.

ii) Sodium atom and sodium ion both have 11 protons in nucleus and both have 12 neutrons in the nucleus, ie no differences in nucleus. Sodium atom has one more electron than sodium ion and has three shells containing electrons. **PLUS** Sodium ion has a positive charge of one, whereas sodium atom is neutral.

c) lead nitrate

d)  $K_2S$

e) i) 7 atoms ii) 14 atoms

12. a) 11 12 1

b) 8 2 2,8 in diag.

c) Aluminium is  $+3$  and oxygen is  $-2$

Two aluminium ions (not atoms) balance three oxygen ions charge on  $Al_2O_3$  is balanced / neutral.

d)  $K_2O$   $Mg(NO_3)_2$   $CaS$   $(NH_4)_2SO_4$

e) copper chloride zinc hydroxide potassium fluoride

f) Next to each other (or equivalent statement eg O in Gp 16 and F in 17) O has 6 electrons in outer shell and F has 7 electrons in outer shell.

F forms  $-1$  ions and O forms  $-2$  ions F gains 1e and O gains 2e.

13. a)

Al	13	27	13	(i)13	(ii)14
C	(iii)6	12	(iv)6	6	6
$Na^+$	11	23	11	10	12
$O^{2-}$	8	16	8	10	8

b) 2,1 : 2,8,5 : 2,8

c) i) Rb  $+1$

ii) Rb  $+1$  / 1 /  $+1$  / one / positive / positive one

d) i) 6 11

ii)  $CaO$   $Cu(OH)_2$   $Na_2CO_3$

iii) magnesium oxide sodium sulfide calcium nitrate

e) Iron in the tablets is a compound/ion/salt Iron in the nails is an element/ metal. The Fe in the tablet is able to be absorbed into the body

A property of the Fe in nail related to its use/non-use as a tablet.